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PROJECT/TASK RADIOACTIVE WASTE MANAGEMENT COMPLEX (RWMC)

SUBTASK Soil Grout Program

EDF PAGE NO. 1 OF 25

SUBJECT

SMALL SCALE SOIL GROUT TEST REPORT

ABSTRACT

A small scale testing program was conducted in FY-1986 to determine the viability of using soil grout to stabilize waste forms. Grout formulation studies were conducted at Oak Ridge National Laboratory (ORNL) which specified a mix containing 40% soil by weight as being optimum. The first phase of the test was to verify the ORNL mix. This was accomplished by making up grout test cylinders ranging from 40 to 60% soil by weight and subjecting them to 3, 7 and 28 day compressive strength tests. The grouts consisting of 40 to 41% soil exhibited a compressive strength of approximately 2500 psi, which tends to support the ORNL recommended grout. The next phase was to inject the soil grout into containers of simulated waste. Two 4 by 4 by 8 ft. plywood boxes, a 50 by 58 by 36 inch metal box, and a 55-gallon drum were loaded with simulated waste (plastic pipe and vessels) for these tests. Soil grout was injected into each of the above containers. With the exception of the metal box, the grout injections went smoothly and reduced the void spaces by 80 to 95%. However, during the metal box grout injection, the quality control of the grout mixing process failed, allowing excessive soil content in the formulation. The only other difficulty experienced was attempting to inject grout into a box containing simulated waste inside a standard liner. That is, the grout did not penetrate the liner, but instead flowed around and under the liner, which tended to reduce the void space between the waste form and the box by buoying the waste up. However, the void space within the waste form was not reduced.

Conclusions derived from these tests are as follows:

1. The plywood box and liner combination is not adequate for grout injection.
2. Quality control concerning the amount of soil in the grout mix is critical.
3. Soil grout injection is a viable process for providing waste form stability, and is effective in significantly reducing void spaces.
4. Soil grout will enable the RWMC to exceed Federal regulatory requirements for disposal site stability and associated void space reduction.
5. The small scale soil grout test was a success.

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The test results and conclusions support the recommendation that a soil grout facility and operation for low level waste (LLW) disposal at the Radioactive Waste Management Complex (RWMC) should be actively pursued. However, it is important that soil grouting be applied to both interior (waste form) and around disposed containers in the active pit to be effective.

INTRODUCTION

PURPOSE: The purpose of this program was twofold: first, validate the soil grout injection process as a viable and justifiable process; and second, to determine to what extent this technology would enhance the RWMC compliance to DOE Order 5820.2 and 10 CFR 61 requirements.

OBJECTIVE: To verify the viability of adapting existing soil grout technology as a medium for stabilizing both the waste form and an active disposal pit.

BACKGROUND: The Subsurface Disposal Area (SDA), located within the RWMC at the Idaho National Engineering Laboratory (INEL), is an active radioactive low-level waste disposal site. The waste is disposed via shallow land burial practices and therefore, waste zone stability becomes of paramount importance. Subsidence within the buried waste zone at the SDA has been, and continues to be of concern for the site operators. Not only does this subsidence provide a pathway for the intrusion of water and biota into the waste, but it also represents a potential hazard to the health, safety and environment of the RWMC, INEL and in turn, the off-site public.

Subsidence is caused by a lack of stability within the waste zone, with the main culprit being void spaces both within and around the disposed containers. DOE Order 5820.2, Chapter II, "Management of Low Level Waste," and 10 CFR 61, Paragraph 61.56, "Waste Characteristics," require waste zone stability to assure that the buried waste isolation is maintained. The structural stability can be achieved by either processing or treating the waste, or by placing the waste into a container or structure capable of providing this stability.

Therefore, in order to minimize the active SDA maintenance requirements, stability must be achieved. Also, stability is a prerequisite to site closure. That is, without stability of the disposal site, a successful closure cannot be achieved. To achieve this stability, the RWMC submits

that the void volumes within the waste zone must be filled. Waste form stability, without accounting for voids around the containers, is only part of the solution. Also, providing a stable container or structure is considered a costly interim method that puts off the instability until sometime in the future, which may or may not be acceptable. Thus, grouting appears to be the ideal solution if significant void space reduction, both within and around the disposed container, can be demonstrated.

The small scale grout tests project documentation is provided by this report, a project logbook, and a complete set of photographs. The photographs are kept with the project file and can be viewed upon request.

SOIL GROUT: SMALL SCALE TESTS

During the summer months of FY-86, the experimental portion of the small scale soil grout test was performed. Several waste containers were filled with simulated waste and then filled with a soil grout. The grout mixing and injection were performed at the RWMC in WMF-602. Several soil grout formulations were mixed and tested at CFA-605.

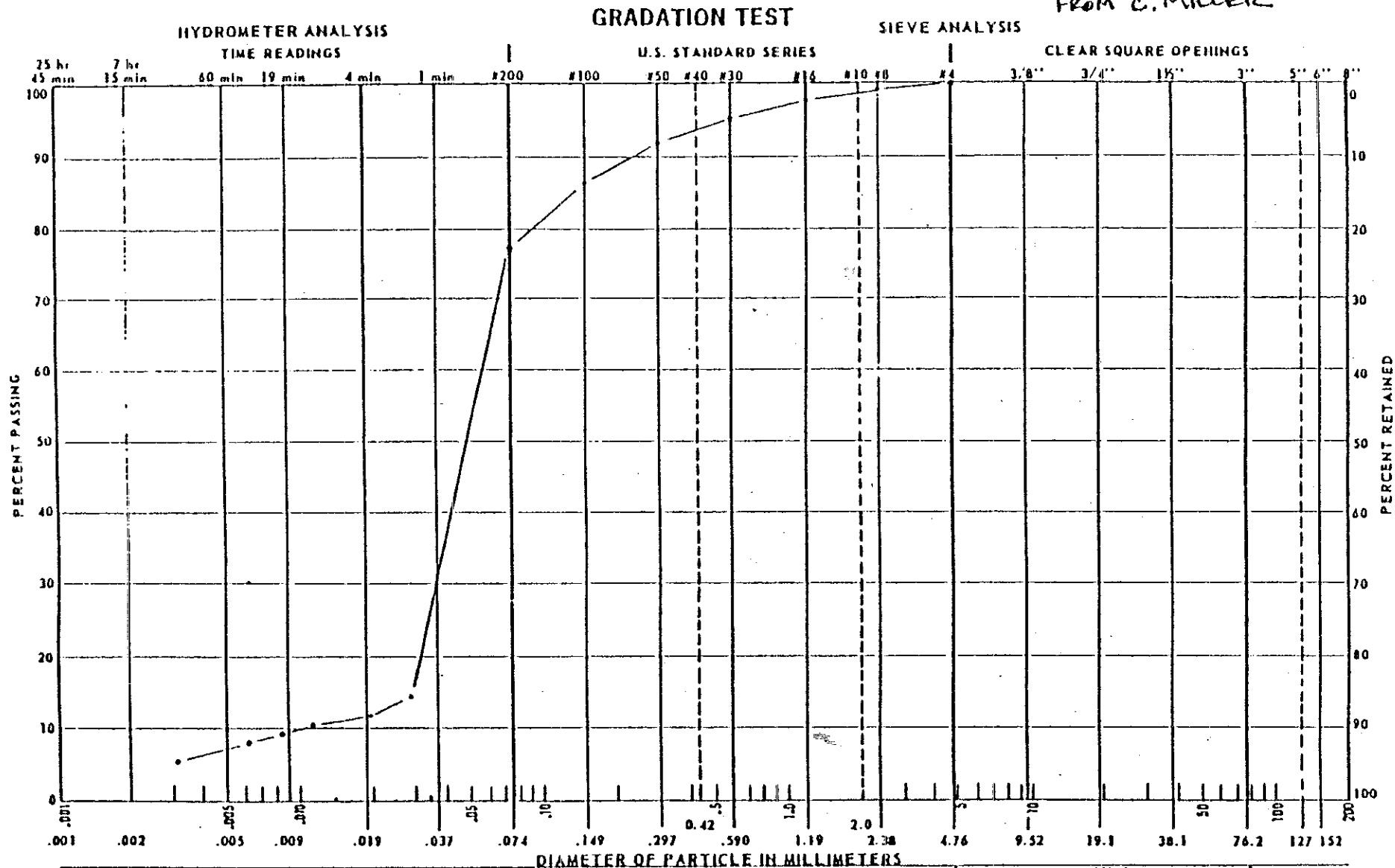
Materials for the small scale soil grout test program were Type II and III Portland cement, ASTM Class C fly ash, screened soil and tap water. The cement was procured from Ash Grove Cement West, Inc. in Inkom, Id. The ASTM Class C fly ash was procured from Ross Inland Dry Mix of Portland, Oregon. The soil was taken from an area near the RWMC and was screened over a 1/4 inch screen.

The soil grout was mixed and pumped with a ChemGrout CG-500 all electric grout plant. The cement and fly ash were in 94 and 80 pound sacks respectively and were fed into the mixers by hand. The soil was fed into the mixers from buckets that were filled and dumped by hand. The soil had a bulk density of approximately 70 lbs/cu. ft. after screening. Table 1 shows the total amount of materials used to mix the grout. Figure 1 shows the gradation of the soil used to mix the grout.

TABLE 1 TOTAL MATERIALS USED

<u>COMPONENT</u>	<u>AMOUNT USED</u>	
Cement	79.0 sacks	7,426 lbs
Fly ash	39.5 sacks	3,160 lbs
Water	953.8 gallons	7,573 lbs
Soil	185.4 cu.ft.	<u>12,976 lbs</u>
TOTAL		31,135 lbs

SAMPLE
FROM C. MILLER



FINES		SAND			GRAVEL		COBBLES
		FINE	MEDIUM	COARSE	FINE	COARSE	
CLASSIFICATION SYMBOL <u>ML</u>		ATTERBERG LIMITS		SPECIFIC GRAVITY		NOTES	
Gravel	_____ %	Liquid Limit _____ %		Minus No. 4 _____			
Sand	_____ %	Plasticity Index _____ %		Plus No. 4 _____			
Fines	_____ %	Shrinkage Limit _____ %		Bulk _____ Apparent _____			
SAMPLE NO. _____		HOLE NO. _____		DEPTH _____ ft (_____ m)			

Figure 1. Soil Gradation.

MIX TESTING

Several soil grout mixes were tested in an attempt to further optimize the mix provided by ORNL (mix #1). The mixes were tested for compressive strength and qualitative observations were made of viscosity and bleed water generated during curing. Compressive strengths were obtained for 3, 7 and 28 day test cylinders. Table 2 shows the mix proportions for the test cylinders. The test cylinders were formed in 3 x 6 inch waxed cardboard molds. The grouts were mixed using a small bench scale mixer.

TABLE 2 MIX PROPORTIONS

MIX NO.	% BY WEIGHT			
	CEMENT	FLY ASH	SOIL	WATER
1 (ORNL)	25.00	10.00	40.00	25.00
2	23.87	10.00	41.13	25.00
3	22.55	10.00	42.44	25.00
4	21.22	10.00	43.77	25.00
5	19.89	10.00	45.09	25.00
6	18.57	10.00	46.42	25.00
7	17.24	10.00	47.75	25.00
8	5.00	10.00	60.00	25.00

Table 3 shows the 3, 7 and 28 day compressive strengths for the mixes.

TABLE 3 COMPRESSIVE STRENGTH (PSI)

MIX NO.	3 DAYS	7 DAYS	28 DAYS
1 (ORNL)	651	1570	2490
2	630	1499	2546
3	538	1308	2037
4	467	1153	1924
5	375	1033	1994
6	438	835	1683
7	375	750	1429
8	0*	0*	0*

* The test cylinders for mix 8 had severe shrinkage cracks and broke when handled.

Observations made of the test mixes during mixing, curing and before performing the compressive strength test are as follows:.

The mix tests show that the mix provided by ORNL is the best all around mix that was tested. However, if a slight amount of bleed water can be tolerated, mix 7 would be the ideal mix to use. Further testing could lead to a mix that would maximize the amount of soil used while minimizing the amount of cement used and the amount of bleed water generated.

OBSERVATIONS OF MIX TESTS

Fluidity Observations: All eight of the mixes tested were very fluid and poured well. The typical mix had the liquid appearance of thin pancake batter. The ORNL mix had a viscosity of approximately 20 centipoise.

Bleed Water Observations: Mix 1 generated the least bleed water, which was just barely perceptible on top of the cylinder. The other mixes generated increasing amounts of bleed water which were only slightly more perceptible than that of Mix 1. Mix 8 generated an intolerable amount of bleed water, nearly 1/4 inch on top of the cylinder.

Color Observations: The color of Mix 1 was gray with a slight brown cast. The other mixes were progressively more brown in color but were still predominantly gray, except Mix 8 which was predominantly brown with only a trace of gray.

Surface Crack Observations:

Three Day Cylinders:

Mix 3 showed some surface cracks.

Mix 8 had a severe circumferential crack and broke when handled.

Seven Day Cylinders:

Mixes 4, 6 and 7 showed some surface cracks.

Mix 5 had a narrow crack that was nearly circumferential.

Mix 8 had a severe circumferential crack and broke during handling.

Twenty-Eight Day Cylinders:

Mixes 3, 5 and 7 showed some surface cracks.

Mix 4 had a narrow crack that was nearly circumferential.

Mix 8 had a severe circumferential crack and broken when handled.

The cylinders showed some discoloration, which was most likely caused by the wax on the molds.

CONTAINER FILLING TESTS

Several containers were filled with soil grout mix No. 1 as a part of the testing program. An old style 4x4x8 foot plywood box, a new style 4x4x8 foot plywood box, a 55 gallon drum and a nonstandard metal box were filled with a simulated waste and injected with soil grout. The simulated waste contained pieces of PVC pipe and PVC vessels cut into random lengths between 2 and 5 feet long. The two plywood boxes were placed in a support fixture to insure that the box sides would not fail during the grout injection operations. Thermocouples were placed in the new plywood box to record the temperatures generated by the curing grout.

Grout materials injected into the containers were: tap water, type II and III Portland cement, ASTM Class C fly ash and local soil that had been screened over a screen with 1/4 inch openings.

The grout was mixed with a ChemGrout CG-500 all electric grout plant. The grout plant had two paddle type mixers and a Robins and Myers Moyno 2J6 CDQ pump. The soil grout was batch mixed and had the formulation shown in Table 4. The mix was only slightly different from the ORNL mix and was a convenient mix for staging materials. The mix flowed very well with an average pumping pressure of 17 psig through a 50 foot long, 1-1/4 ID hose. Figure 2 shows a sketch of the grout injection setup.

TABLE 4 SOIL GROUT BATCH FORMULATION

<u>Component</u>	<u>Amount Used</u>	<u>% By Weight</u>
Cement	2 sacks 188 lbs	24.1
Fly Ash	1 sack 80 lbs	10.3
Water	23 gallons 192 lbs	24.6
Soil	4.57 cu.ft. 320 lbs	41.0
TOTAL	780 lbs	100.0

The grout injection probe, Figure 3, was constructed of 1 1/4 inch schedule 40 carbon steel pipe and fittings. The valves were standard bronze ball valves. The pressure gage was isolated from the grout by a rubber diaphragm and was filled with instrument oil that transmitted the grout pressure to the gage. The two gages were calibrated by the EG&G Idaho Quality Standard Laboratory.

TEST RESULTS AND OBSERVATIONS.

Old Plywood Box: The old plywood box was filled primarily with PVC vessels that had been cut into two pieces. The pieces were randomly placed and the yellow PVC liner was overlapped over the top of the waste, as is the usual practice with waste packaging. When the filling operation was first started an attempt was made to penetrate the liner with the grout injection probe, see Figure 3. Grout was pumped until the top of the box lifted about 1/2 inch, with no grout spilled. It was observed

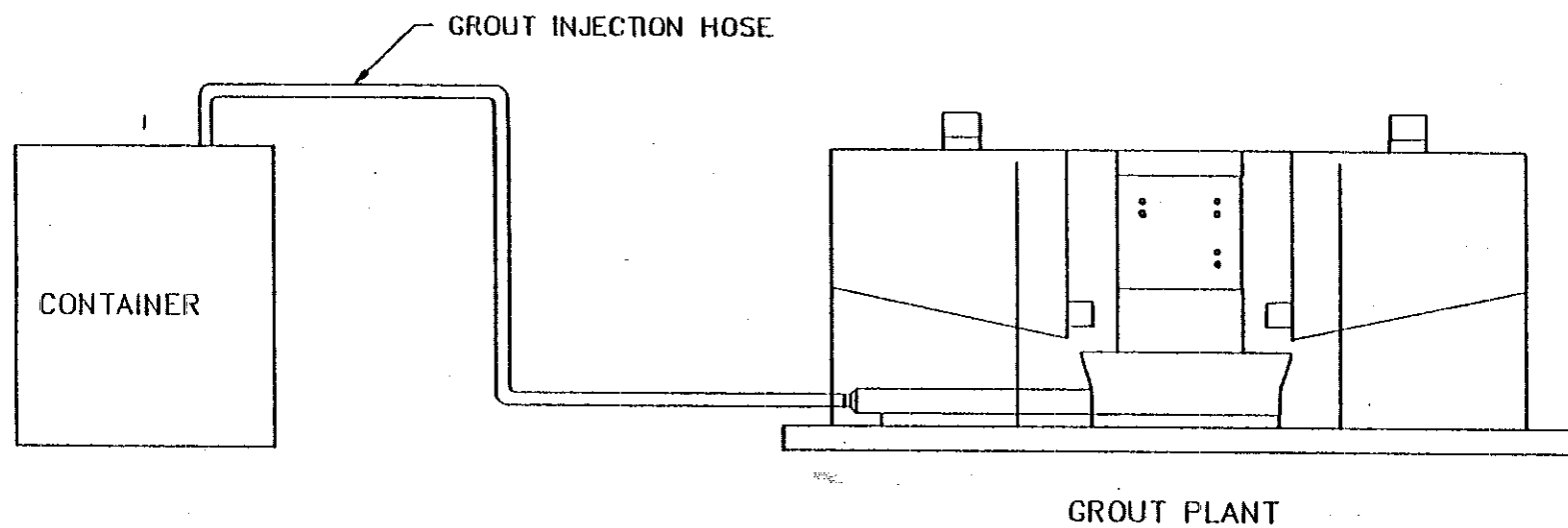


FIGURE 2 SMALL SCALE SOIL GROUT TEST EQUIPMENT LAYOUT

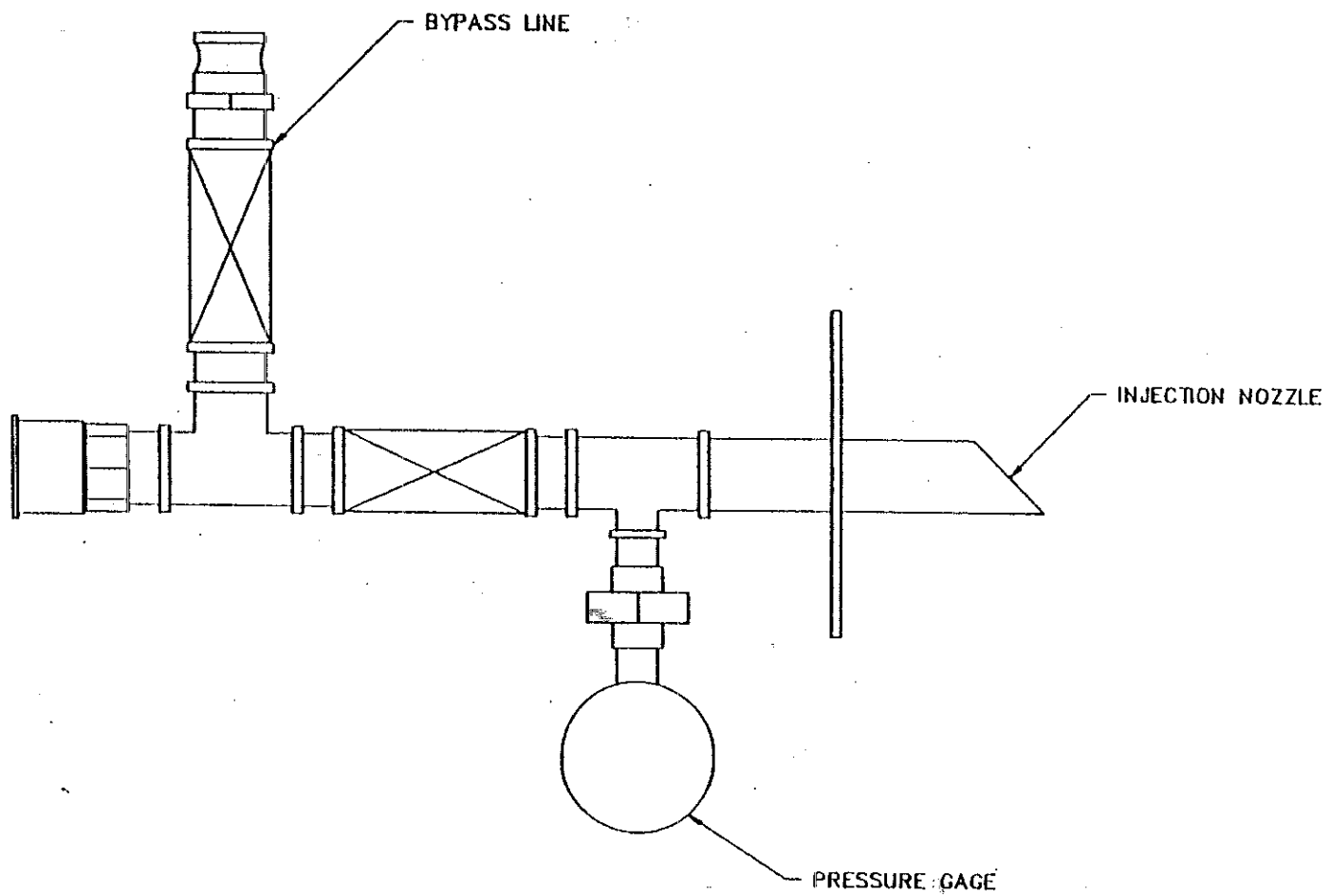


FIGURE 3 GROUT INJECTION PROBE

that the liner had not been punctured and that the grout had flowed around the liner and was filling the void space under the liner. The box lid was removed, the liner pulled back and hung over the sides of the box and the box lid replaced. The filling operation was resumed and grout was pumped until a small amount of grout spilled over the sides of the box from the crack between the box lid and body. Table 5 shows the amount of each component used.

TABLE 5 MATERIALS USED FOR OLD PLYWOOD BOX

COMPONENT	AMOUNT USED	
Cement	32 sacks	3,008 lbs
Fly ash	16 sacks	1,280 lbs
Water	368 gallons	3,070 lbs
Soil	73.1 cu.ft.	5,120 lbs
TOTAL		12,478 lbs

Nonstandard Metal Box: A nonstandard metal box was manufactured from two pieces of scrap metal boxes (M-III bins) found behind WMO-601. The box had external dimensions of 50.5 x 58.5 x 36 inches (wxl x h). The box was made of 12 gage steel and was of welded construction. Pieces of PVC pipe and vessel were placed in the box, the top was welded on and two holes (1 injection and 1 vent) were cut in the top of the box. The grout injection operation was progressing smoothly until near the end. Near the end of the filling operation, the grout became thick and had the fluid character of toothpaste. The pressure gage at the pump outlet read nearly 300 psig and the gage at the injection nozzle read about 20 psig. The pump motor tripped off and before the panel could be opened and the motor reset, the grout started to set up in the equipment and operations were ceased to clean grout from the pump, pressure gages and injection nozzle. All of the equipment was saved with the exception of 50 feet of grout hose. Reasons for the grout thickness will be discussed later along with other operational problems. Table 6 shows the amount of material pumped into the metal box.

TABLE 6 MATERIAL USED FOR THE METAL BOX

COMPONENT	AMOUNT USED	
Cement	14 sacks	1,316 lbs
Fly ash	7 sacks	560 lbs
Water	161 gallons	1,343 lbs
Soil	36.8 cu.ft.	2,576 lbs
TOTAL		5,795 lbs

55 Gallon Drum: A standard 55 gallon drum was filled with pieces of PVC pipe and vessels and filled with soil grout mix 1. There were no incidents or problems associated with the filling operation. Table 7 shows the amount of materials used to fill the drum.

TABLE 7 MATERIALS USED FOR THE 55 GALLON DRUM

<u>COMPONENT</u>		<u>AMOUNT USED</u>
Cement	3 sacks	282 lbs
Fly ash	1-1/2 sacks	120 lbs
Water	33-3/4 gallons	282 lbs
Soil	6.9 cu.ft.	480 lbs
TOTAL		1,164 lbs

Because of the grout problems associated with the metal box, extra care was taken to assure proper mix proportions were observed. These precautions resulted in a smooth and trouble-free grout injection operation.

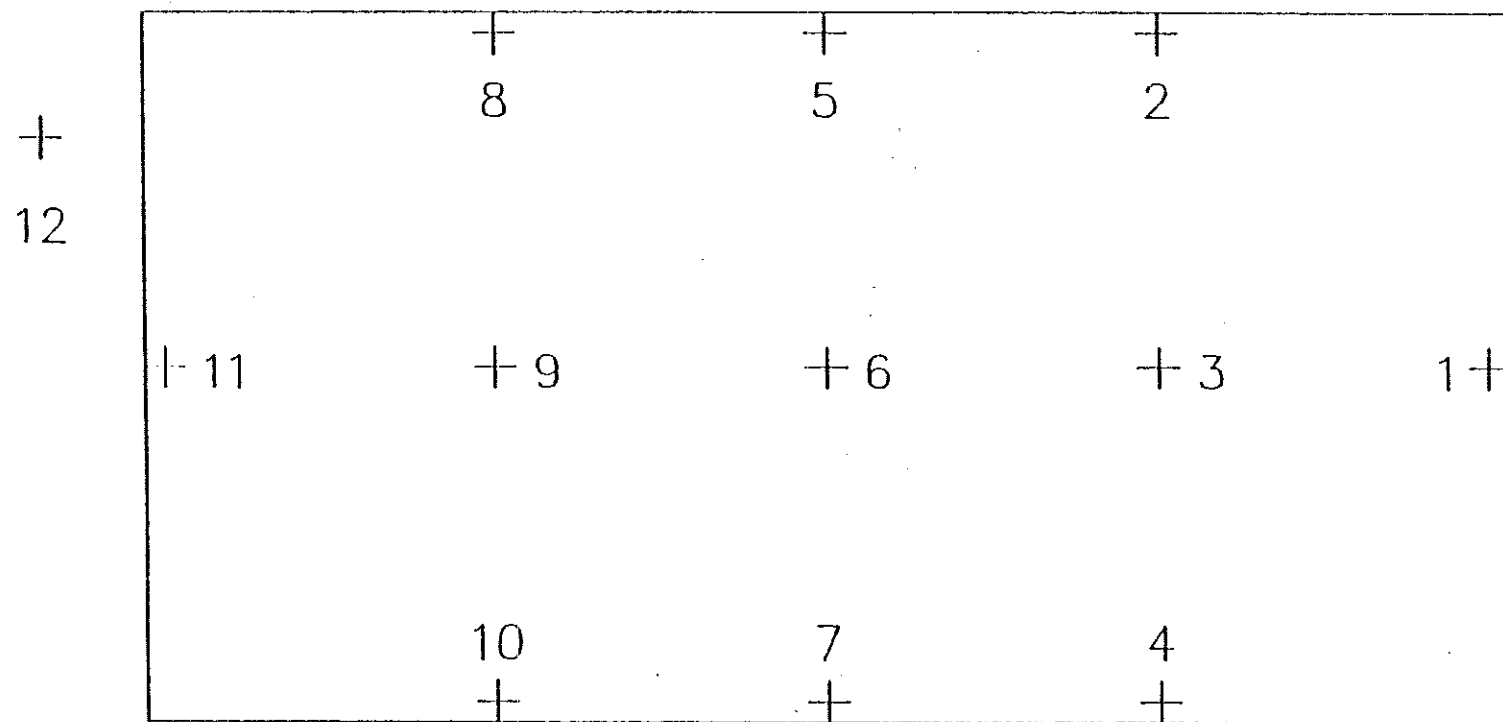
New Plywood Box.

The new plywood box was filled primarily with pieces of PVC pipe of various lengths and diameters. The box liner was draped over the sides of the box and trimmed off after the box lid was nailed down. The box was provided with twelve (12) thermocouples to measure the maximum temperature reached during curing. The thermocouples were arranged as shown in Figure 4. The results of the temperature measurements are included as Appendix 1. The maximum temperature reached was 190F at the center of the box and occurred 40 hours after the box was filled with soil grout. The grout injection operation went very smoothly with only one minor problem. Some of the cement sacks had become wet and the cement had hydrated and had setup very hard. When the first sack of cement was added to the mixer, several chunks of hard cement caused the mixer paddles to become momentarily jammed. Several sacks of cement had to be rejected because of this problem. Table 8 shows the amount of materials used to fill the box.

TABLE 8 MATERIALS USED FOR THE NEW PLYWOOD BOX

<u>COMPONENT</u>		<u>AMOUNT USED</u>
Cement	30 sacks	2,820 lbs
Fly ash	15 sacks	1,200 lbs
Water	345 gallons	2,878 lbs
Soil	68.5 cu.ft.	4,800 lbs
TOTAL		11,698 lbs

After the grout had set for 28 days, this box was subjected to a compressive strength load test. Test weights were added in increments until all test weights at the CF gantry crane site, had been used. The grouted box supported 204,000 lbs. with no visible damage. In fact, there was no joint separation, no compression, no noise at all. The box appeared as structurally strong as a solid concrete block.



+ THERMOCOUPLE LOCATION

FIGURE 4 THERMOCOUPLE LOCATIONS (PLAN VIEW)

DESTRUCTIVE EXAMINATIONS

All of the grouted containers were subjected to destructive examinations to determine the void filling efficiency of the grouting operation. In addition to destructive examination, the new 4x4x8 foot plywood box was load tested to determine its load bearing capacity.

Old Plywood Box: The destructive examination of the old plywood box was done by removing the sides of the box and taking core samples from the top and one side of the box. The destructive examination of the old plywood box showed a monolithic block where the grout had flowed between the bottom of the box and the liner. Voids were left where the liner crossed the 2x4 braces on the sides of the box and at the 4x4 corner posts. Two cores were drilled in the grout-waste matrix to determine the void filling efficiency. It was observed that pipes with one closed end did not fill as well as pipes with both ends open. This was very apparent when the pipes were oriented vertically and the caps trapped large air volumes in the pipes. The voids resulted when the trapped air and grout reached an equilibrium. The overall void filling efficiency was estimated at 80%.

Nonstandard Metal Box: The metal box was examined by removing the sides of the box with a cutting torch. Some of the exposed PVC pipe was scorched during the cutting operations but no serious damage to the grout block occurred. The sides were smooth and very few voids were visible at the surface near the bottom of the box. At the top of the box voids were quite visible and the surface of the grout was quite rough. At the very corner of the box where the final injection was done the grout had a rope like appearance and was visibly different from the rest of the grout. Until the consistency of the grout changed (see filling description) the void filling appeared to have an efficiency of 80%. The reason for the change in grout viscosity appeared to be a change in the mix formulation. Calculations revealed that more soil than anticipated was used and the box was still only approximately 80% filled. The subsequent 55-gallon drum test appeared to substantiate the grout formulation and excessive soil theory.

55 Gallon Drum: The 55 gallon drum was examined by cutting the drum around the bottom and cutting the barrel lengthwise at two places 180 degrees apart. Very little damage was done to exposed PVC pipe by the cutting torch. The only visible void was at the top of the drum where a pipe had contacted the lid, the void was 6 inches in diameter by 3.75 inches deep. Further examination revealed a capped pipe, which contained some plastic sack material, that had a large air void trapped inside of it. Because of this large capped pipe the void filling efficiency was estimated to be 80%.

New Plywood Box: The new plywood box was load tested at the CFA gantry crane facility. The box withstood a load of 204,000 lbs (total available weights at test site) and did not show any external signs of damage.

The sides and lid were removed from the box to permit examination of the grout block. Several small surface voids were visible on top of the block. Some of the surface voids were small air bubbles that were trapped near the surface, as evidenced by grout bridges that were observed over the voids. Voids were also left where the liner crossed structural members on the sides of the box. These voids occurred as rounded corners on both sides of each structural member, and were caused by the poly liner, which lined the box.

Several leaks were observed in the PVC liner. Most of these leaks occurred near the structural members on the sides of the box. The leaks could have been caused either by placing the waste in the box or stretching caused by the grout.

When the liner was peeled away from the grout block, several small shrinkage cracks were observed on the surface of the block. Several pieces of the PVC pipe were also exposed at the surface. Holes were drilled into two of the exposed pipes and grout was found in both pipes. Several pipe ends were observed at the surface of the block and were found to contain grout. The void filling efficiency was estimated to be approximately 95%.

OPERATIONAL PROBLEMS

During the grout mixing and box filling operations, several problems were noted. The most noteworthy problems involved labor intensive material handling and quality control. During the first operation, the old plywood box, materials were lifted from essentially floor level to chest high when added to the mixers. As each operation progressed, the laborers handling the materials became tired and therefore less efficient. This problem was corrected by constructing a wooden platform about 2 feet high and having the materials supported on a fork lift at a convenient height thus significantly reducing the work associated with material handling.

During the filling operation involving the nonstandard metal box, quality control became an obvious problem. Near the end of the operation when the people involved were not paying close attention to the operation, the mix was inadvertently altered by adding more soil than normal to the mix. The grout became progressively thicker until at last it became too thick to pump and the pump motor tripped off. At this point the operation had to be suspended and the equipment torn down and cleaned to prevent grout from solidifying in the pump and injection nozzle.

Another problem associated with quality control was that of grout lumps partially blinding the screen over the feed hopper on the pump. The lumps were caused by rapidly adding the dry solids to the mixer. If the dry solids could have been added to the mixer in a slower, more controlled manner, fewer lumps would have been formed.

During the operations a minor amount of dust and grout splatter were observed. Most of the dust was associated with dumping cement and flyash into the mixers and shoveling and screening the soil. Grout was also splattered out of the mixers by the mixing action of the paddles. The degree of tilt of the mixer also influenced the amount of splattering.

Most of the operational problems associated with the grout mixing operations could be easily solved by substituting the labor intensive methods with an automated dry solids handling system. A properly designed system could deliver the dry solids to the mixer in the proper proportions and at the proper rate. Dust and grout splatter can be controlled through good design and construction.

The 80 to 95% void filling efficiency witnessed could be increased by eliminating trapped air space and vibrating the container during the filling operation. A vibrator could be easily attached to the fixture supporting the container.

ALTERNATIVES

Two alternatives to waste form stability exist, but they both involve containment; that is, the waste container or a structure in which to place the waste package. These two alternatives were not part of this test plan and will therefore only be casually addressed.

Treatment of the waste form to provide site stability was chosen because it was considered to be more efficient, effective and would provide protection against subsidence indefinitely. The containment alternatives, which will most certainly contain void spaces, would provide subsidence protection up to approximately 500 years, which may or may not be sufficient, depending on the waste. Using either the high integrity containers or the structure would be expensive and would only delay eventual site subsidence. EDF-153, Scoping Cost for Implementing 10 CFR 61, Subpart D, at the RWMC, although representing a preliminary assessment, appears to support the high cost of providing stability via containment. Treatment of the waste form, on the other hand, could be expected to be reasonably priced once the initial facility and equipment costs have been covered. Also, once the facility is operational, treatment of the waste form would be applied to Class A, B, C and >C waste, at minimal extra cost per unit waste. However, if the containment alternatives are used, it would greatly increase operating costs by adding Class A waste, which is the major waste classification received at the SDA, to the stability containment alternatives inventories. Although Class A waste stability is not necessarily required by 10 CFR 61, it is just as susceptible to void volumes and subsequent subsidence events as any other waste form, and must be considered, whether or not it is segregated from Class B and C wastes. Adding waste form treatment (grout injection) provides both stability and void space reduction adherence and

therefore does not require waste class segregation, which is also time consuming, costly and increases personnel exposure. Also, grout injection can be used to fill void spaces around containers in the disposal site and between the containers and waste site excavation perimeters, thereby providing a stable waste zone that we submit is acceptable for a closure cover base.

FEDERAL REGULATORY CONCERNS

Soil grout injection into and around containers at an active disposal site will enhance compliance to the following federal regulations and requirements. DOE Order 5820.2, Chapter III, b(2) requires mechanical stability; d(1) requires erosion reduction, isolation of waste and active maintenance minimizations; e(9) requires that interaction between waste contents be minimized; and f stipulates the disposal site closure/post-closure requirements. The second regulation is 10 CFR 61, Paragraphs 61.52(4) and (5) requiring that spaces between waste packages be filled to minimize subsidence, and (9) requires closure and stabilization measures, per the approved site closure plan, be carried out as each disposal unit is filled and covered; Paragraph 61.56(b) requires stability of the waste to ensure the waste does not structurally degrade and effect the overall site, and b(3) requires void spaces within the waste and between the waste and its package be reduced to the extent practicable.

A well implemented and maintained soil grout facility and operation will satisfy the above DOE and NRC requirements. It should be noted that, although the RWMC currently complies to the requirements of DOE Order 5820.2, Chapter III, implementing a soil grout program will enhance the disposal site operation, exceed present DOE requirements and ensure compliance in the future. Compliance to 10 CFR 61, however, which is more specific, is questionable; that is, the RWMC presently does not comply with the 10 CFR 61 stability requirements, and only marginally do they comply with the void space requirements. Also, stabilization is a given that must eventually be addressed in the RWMC stabilization and closure plan document, which is presently scheduled for completion in 1996. Therefore, the longer stabilizing of waste zones is put off, the more time consuming, costly and hazardous the final stabilization activity will become for those involved. Therefore, since stability is a given, and soil grout injection is a viable option, it appears that stabilizing both the waste form and active site, using soil grout as operations dictate, would appear to be cost and time efficient, and would minimize the health, safety and environmental hazards to the RWMC, INEL, and the public.

From the above discussion, it is evident that an active soil grout program will greatly enhance RWMC's compliance to the federal regulation, should assure compliance to both present and future stability and void space requirements, and will also assure enhanced closure preparation for the SDA closure activities.

CONCLUSIONS AND RECOMMENDATIONS

The preceding test, observations and discussions have resulted in the following conclusions:

1. Manual soil grout operations are extremely labor intensive and not acceptable for a production scale facility.
2. Injection of soil grout into plywood waste boxes with liners is not effective and the liquid nature of the grout makes a plywood box without a liner unacceptable.
3. Quality control of both the raw materials and the mix constituents is critical to the acceptability of the grouting process.
4. Cement, flyash and soil dust revealed a potential personnel respiratory problem, for which a facility design must provide an adequate solution.
5. The soil grouted simulated waste boxes were extremely heavy, ranging up to 15,000 lbs. However, this did not present a problem because the boxes were supported while being injected, and the grout was self supporting when setup.
6. Standard waste container handling equipment at the RWMC does not have sufficient lifting capacity to dispose of grouted waste containers.
7. The soil grout mixture used in the test sets up quickly such that the grouted containers are self supporting within 24 hours at approximately 70F.
8. Curing temperature of the grout was higher, 190F, than anticipated and should therefore be a consideration in deciding what waste to exclude from grouting.
9. The present plywood boxes have excessive void spaces built into the skids and false bottom design.
10. Soil grout injection is a viable process that was effective in eliminating up to 95% of unwanted void spaces and provide the buried waste site with a significant increase in stability.
11. The small scale soil grout test program was successful in fulfilling both the purpose and objectives of this program.
12. The void space reduction, up to 95%, witnessed during these tests could have been improved by eliminating capped vessels that trap air and by vibrating the container rather than depending on gravity flow to fill the voids.

As a result of the small scale grout tests results and conclusions, the following recommendations are submitted.

1. A production scale grouting facility be pursued to stabilize both the waste form and the disposal location.
2. A different, preferably metal, container for LLW packaging be identified, to replace the existing plywood box and liner.
3. New waste container handling equipment be designed and fabricated to permit the grouted waste containers to be safely and efficiently handled.
4. A mobile grout facility to permit injection of grout around disposed containers in an active pit be pursued.

APPENDIX 1
TEMPERATURE DATA

HOUR	TC 3	TC 6	TC 9	TC 12
0	-	-	-	-
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	-	-	-	-
8	-	-	-	-
9	75.0	75.0	75.0	75.0
10	75.0	75.0	75.0	67.0
11	83.0	83.0	83.0	67.0
12	86.0	86.0	86.0	69.0
13	90.0	90.0	90.0	71.0
14	96.0	96.0	96.0	72.0
15	105.0	105.0	105.0	75.0
16	112.0	112.0	112.0	76.5
17	117.0	117.0	117.0	77.5
18	122.0	122.0	122.0	76.5
19	127.0	127.0	127.0	76.5
20	131.0	132.0	131.0	75.0
21	136.0	137.0	136.0	73.5
22	140.0	141.0	140.0	71.0
23	145.0	146.0	145.0	69.0
24	149.0	151.0	149.0	68.5
25	153.0	155.0	153.0	68.0
26	157.0	159.0	157.0	68.0
27	162.0	163.0	162.0	67.5
28	169.0	172.0	169.0	67.0
29	169.0	172.0	169.0	65.5
30	172.0	174.0	172.0	65.5
31	175.0	177.0	175.0	65.0
32	177.0	179.0	177.0	64.0
33	179.0	181.0	179.0	66.0
34	180.0	182.0	181.0	68.5
35	181.0	183.5	181.5	70.0
36	182.0	184.0	182.5	71.5
37	183.0	185.0	183.5	73.0
38	183.5	186.0	184.5	75.5
39	184.0	186.5	185.0	77.0
40	184.5	187.0	185.5	78.5
41	185.0	187.5	186.0	80.0
42	185.0	188.0	186.5	80.5
43	185.5	188.5	187.0	80.5

44	185.5	189.0	187.0	78.0
45	185.5	189.0	187.5	76.0
46	186.0	189.5	187.5	75.0
47	186.0	189.5	188.0	74.0
48	186.0	189.5	188.0	73.5
49	186.0	190.0	188.0	72.0
50	186.0	190.0	188.0	71.5
51	186.0	190.0	188.0	70.5
52	186.0	190.0	188.0	70.0
53	186.0	190.0	188.0	70.0
54	185.5	190.0	188.0	70.0
55	185.5	190.0	188.0	70.0
56	185.0	190.0	188.0	69.0
57	185.0	190.0	188.0	68.5
58	185.0	189.5	187.5	69.0
59	185.0	189.5	187.5	69.5
60	184.5	189.5	187.5	68.5
61	184.0	189.0	187.0	70.0
62	184.0	189.0	187.0	71.5
63	183.5	188.5	186.5	73.5
64	183.0	188.5	186.5	75.0
65	183.0	188.0	186.0	77.0
66	182.5	188.0	186.0	78.0
67	182.5	188.0	185.5	78.0
68	182.0	187.5	185.5	75.5
69	181.5	187.0	185.0	74.5
70	181.0	187.0	185.0	73.5
71	181.0	187.0	184.5	70.5
72	180.0	186.5	184.0	68.0
73	180.0	186.0	184.0	67.5
74	179.5	186.0	183.5	69.0
75	179.5	185.5	183.0	68.5
76	179.0	185.0	182.5	67.5
77	178.5	185.0	182.0	66.0
78	178.0	184.5	182.0	66.0
79	177.5	184.0	181.5	65.0
80	177.0	183.5	181.0	64.5
81	176.5	183.0	180.5	67.0
82	176.0	183.0	180.0	68.5
83	175.5	182.5	180.0	71.0
84	175.0	182.0	179.5	73.0
85	174.5	181.5	179.0	74.5
86	174.0	181.0	178.5	76.0
87	173.5	181.0	178.0	78.5
88	173.0	180.0	177.0	80.0
89	172.0	180.0	177.0	81.5
90	171.5	179.5	176.0	82.5
91	171.0	179.0	175.5	83.0

92	170.5	178.5	175.0	81.5
93	170.0	178.0	174.5	79.0
94	169.5	177.5	174.0	77.0
95	169.0	177.0	174.0	76.0
96	168.5	176.5	173.0	74.5
97	168.0	176.0	173.0	74.0
98	167.5	176.0	173.0	72.5
99	167.0	175.5	172.0	71.0
100	166.5	175.0	171.5	71.0
101	166.0	174.5	171.0	71.0
102	165.5	174.0	170.5	70.0
103	165.0	174.0	170.0	69.0
104	164.0	173.0	169.0	68.5
105	164.0	172.5	169.0	70.0
106	163.0	172.0	168.0	71.0
107	162.5	171.5	167.5	72.5
108	162.0	171.0	167.0	75.0
109	161.0	170.0	166.0	76.0
110	160.5	169.5	166.0	77.0
111	160.0	168.5	165.5	79.5
112	159.5	168.5	165.0	78.0
113	159.0	168.0	164.0	81.5
114	158.5	167.5	163.5	83.5
115	158.0	167.0	163.0	83.0
116	157.0	166.5	162.0	82.0
117	156.5	166.0	161.5	80.5
118	156.0	165.0	161.0	79.0
119	156.0	165.0	161.5	78.0
120	155.0	164.5	160.0	77.5
121	154.5	164.0	159.5	77.0
122	154.0	163.5	159.0	76.0
123	153.5	163.0	159.0	75.5
124	153.0	162.5	158.0	73.0
125	152.5	162.5	157.5	72.0
126	152.0	162.0	157.0	70.5
127	151.5	161.0	156.0	69.5
128	151.0	161.0	156.0	68.5
129	150.5	160.0	155.5	70.5
130	150.0	160.0	155.0	72.5
131	150.0	159.5	155.0	76.0
132	149.0	158.5	154.0	77.5
133	148.0	158.0	153.5	80.5
134	147.5	157.5	153.0	83.5
135	147.5	157.5	153.0	81.0
136	147.0	156.5	152.0	79.0
137	146.5	156.5	151.5	77.5
138	146.0	156.0	151.0	76.0
139	145.5	155.0	150.5	77.0

140	144.5	154.5	150.0	76.0
141	144.5	154.5	149.5	77.0
142	144.0	154.0	149.0	75.0
143	144.0	154.0	149.0	73.5
144	143.5	153.0	148.5	72.5
145	143.0	153.0	148.0	71.5
146	142.5	152.5	147.5	71.0
147	142.0	152.0	147.0	69.0
148	141.0	151.0	146.0	69.0
149	141.0	151.0	146.0	67.5
150	140.5	150.5	145.5	67.0
151	140.0	150.0	145.0	66.0
152	139.5	149.5	144.5	67.0
153	139.0	149.0	144.0	68.5
154	138.5	148.5	143.5	70.5
155	138.5	148.0	143.5	73.5
156	137.5	147.5	142.5	76.0
157	137.0	147.0	142.0	80.0
158	137.0	147.0	142.0	80.0
159	136.5	146.5	141.5	81.0
160	136.5	146.0	141.0	82.5
161	136.0	145.5	140.5	84.0
162	135.5	145.0	140.0	85.0
163	135.0	144.5	139.5	84.0
164	134.0	144.0	139.0	83.0
165	134.0	143.5	138.5	80.5
166	133.5	143.0	138.0	78.0
167	133.0	143.0	138.0	75.0
168	133.0	143.0	137.5	74.0
169	132.5	142.5	137.0	72.5
170	132.0	142.0	137.0	71.5
171	131.5	141.5	136.5	70.0
172	131.5	141.0	136.0	69.5
173	131.0	141.0	136.0	68.0
174	130.5	140.0	135.5	68.0
175	130.0	140.0	135.0	67.0
176	130.0	139.5	134.5	67.5
177	129.5	139.0	134.0	69.0
178	129.0	138.5	133.5	71.0
179	128.5	138.0	133.0	73.0
180	128.0	138.0	133.0	76.0
181	127.5	137.0	132.5	78.0
182	127.0	136.5	132.0	80.0
183	126.5	136.5	131.5	81.0
184	126.0	136.0	131.0	83.0
185	126.0	135.5	130.5	84.0
186	126.0	135.0	130.0	85.0
187	125.5	135.0	129.5	84.5

188	125.0	134.5	129.5	83.0
189	125.0	134.0	129.0	79.0
190	124.5	134.0	128.5	77.0
191	124.0	133.5	128.5	75.0
192	123.5	133.0	128.0	73.5
193	123.0	133.0	128.0	73.5
194	123.0	132.5	127.5	73.0
195	122.5	132.0	127.0	72.5
196	122.5	131.5	126.5	72.0
197	122.0	131.5	126.0	71.5
198	121.5	131.0	126.0	71.5
199	121.0	130.5	125.5	71.5
200	121.0	130.0	125.0	70.5
201	120.5	130.0	125.0	70.0
202	120.0	129.5	124.5	71.0
203	119.5	129.0	124.0	71.5
204	119.5	128.5	123.5	73.5
205	119.5	128.0	123.5	74.5
206	119.0	128.0	123.0	75.0
207	118.5	127.5	122.5	76.5
208	118.0	127.0	122.5	77.5
209	118.0	127.0	122.0	78.5
210	118.0	126.5	121.5	74.0
211	117.5	126.0	121.0	72.5
212	117.5	126.0	121.0	71.5
213	117.5	126.0	121.0	70.5
214	117.0	125.5	120.5	69.0
215	116.5	125.0	120.0	68.0
216	116.0	125.0	120.0	68.0
217	116.0	124.5	119.5	67.0
218	116.0	124.0	119.5	66.0
219	115.5	123.5	119.0	65.5
220	115.0	123.5	119.0	65.5
221	115.0	123.0	118.5	64.5
222	114.5	122.5	118.0	64.0
223	114.0	122.5	118.0	63.5
224	114.0	122.0	117.5	64.5
225	114.0	122.0	117.0	66.0
226	113.5	121.5	117.0	67.5
227	113.0	121.0	117.0	67.0
228	112.5	120.5	116.5	67.0
229	112.5	120.5	116.5	66.5
230	112.0	120.0	116.0	67.5
231	112.0	120.0	115.5	69.0
232	111.5	119.5	115.0	71.0
233	111.5	119.0	114.5	72.5
234	111.0	119.0	114.5	72.5
235	111.0	118.5	114.5	72.5

236	110.5	118.0	114.0	71.5
237	110.5	118.0	113.5	70.0
238	110.0	117.5	113.5	68.0
239	110.0	117.5	113.0	67.0
240	109.5	117.5	112.5	66.0
241	109.0	117.0	112.5	65.5
242	109.0	116.5	112.5	65.0
243	109.0	116.5	112.0	64.0
244	108.5	116.0	111.5	64.0
245	108.0	116.0	111.5	63.5
246	108.0	115.5	111.0	62.5
247	107.5	115.0	111.0	61.5
248	107.5	115.0	111.0	61.5
249	107.5	114.5	110.5	62.5
250	107.0	114.0	110.5	64.0
251	106.5	114.0	110.0	64.5
252	106.5	113.5	109.5	65.5
253	106.0	113.5	109.0	66.5
254	106.0	113.0	109.0	68.0
255	105.5	112.5	109.0	69.0
256	105.5	112.5	108.5	69.0
257	105.0	112.0	108.0	69.0
258	105.0	112.0	108.0	68.0
259	104.5	111.5	107.5	68.0
260	104.5	111.5	107.5	67.5
261	104.0	111.0	107.0	66.5
262	104.0	111.0	107.0	66.0
263	104.0	111.0	107.0	65.0
264	104.0	110.5	106.5	65.0
265	103.5	110.5	106.5	64.5
266	103.0	110.0	106.0	63.5
267	103.0	109.5	106.0	62.5
268	102.5	109.5	105.5	62.0
269	102.5	109.5	105.5	62.0
270	102.5	109.0	105.0	62.0
271	102.0	108.5	105.0	61.5
272	101.5	108.5	104.5	62.0
273	101.5	108.0	104.0	62.5
274	101.0	107.5	104.0	64.0
275	100.5	107.5	104.0	66.0
276	100.5	107.5	103.5	68.0
277	100.0	107.0	103.0	69.5
278	100.0	106.5	102.5	70.5
279	99.5	106.5	102.5	73.5
280	99.5	106.0	102.0	74.0
281	99.0	105.5	102.0	74.0
282	98.5	105.5	102.0	73.0
283	98.5	105.5	101.5	71.5

284	98.5	105.5	101.0	70.0
285	98.5	105.0	101.0	68.5
286	98.5	105.0	101.0	67.0
287	98.0	104.5	100.5	66.0
288	97.5	104.0	100.5	65.0
289	97.5	104.0	100.5	65.0
290	97.5	104.0	100.5	65.5
291	97.0	103.5	100.0	65.0
292	97.0	103.5	100.0	65.0
293	97.0	103.0	99.5	64.0
294	97.0	103.0	99.0	63.0
295	96.5	102.5	99.0	63.0
296	96.5	102.5	99.0	63.5
297	96.0	102.0	98.5	65.0
298	96.0	102.0	98.5	66.0
299	95.5	101.5	98.0	67.0